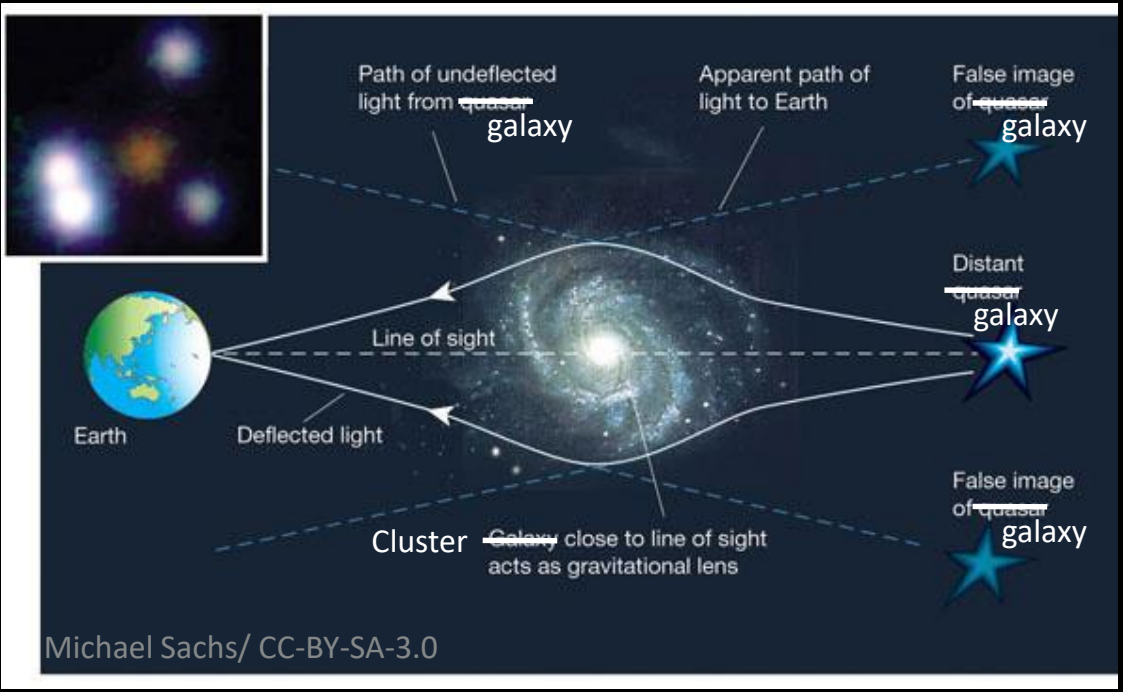
Cluster Weak Lensing with SuperBIT

Dr. Jacqueline McCleary

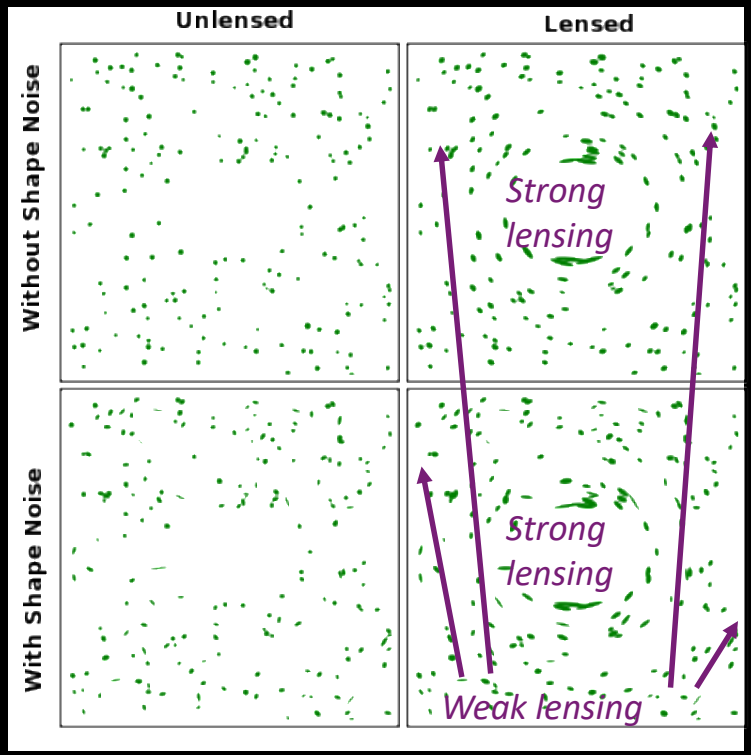
www.jpl.nasa.gov/spaceimages

Jet Propulsion Laboratory
California Institute of Technology

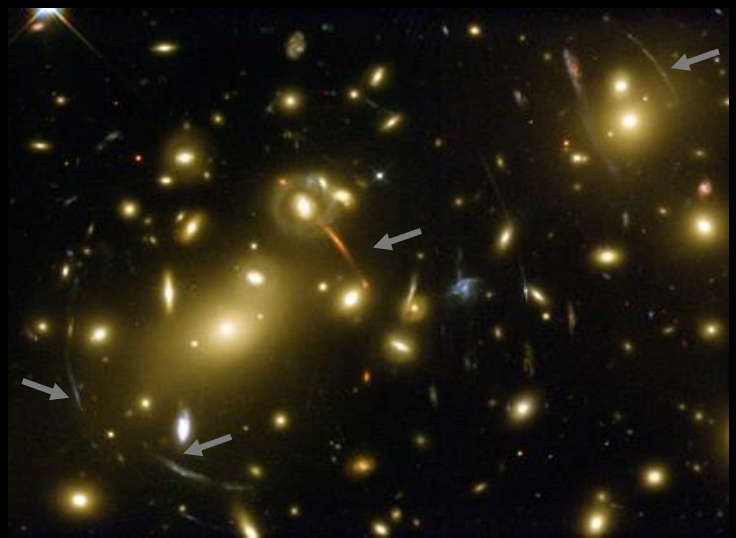
How Weak Lensing Works in Clusters



SEE CORRELATED DISTORTIONS OF GALAXY SHAPES, CAUSED BY INTERVENING GRAVITATIONAL

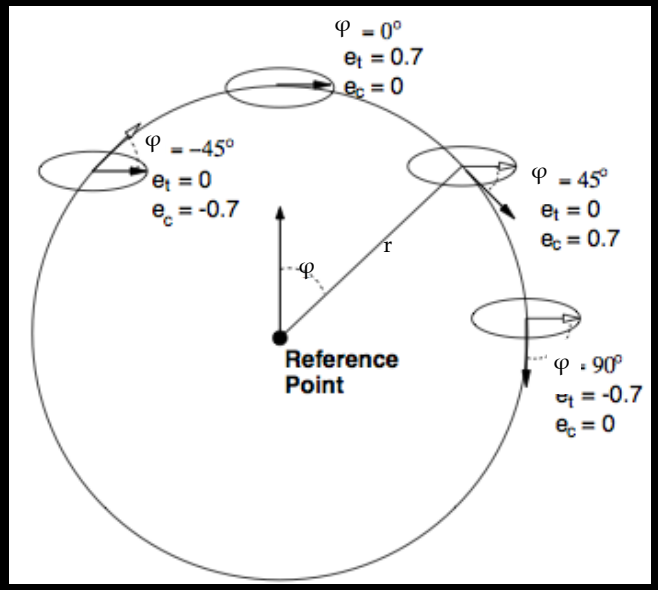


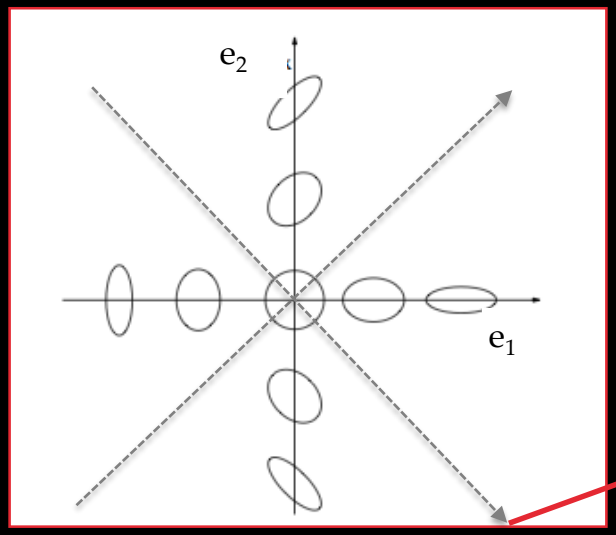
Famous strong lensing example: Abell 2218



Lensing Signal from Galaxy Ellipticity

- Weak lensing signal/convergence $\kappa(\mathbf{r})$ is measured from galaxies' **tangential ellipticity**





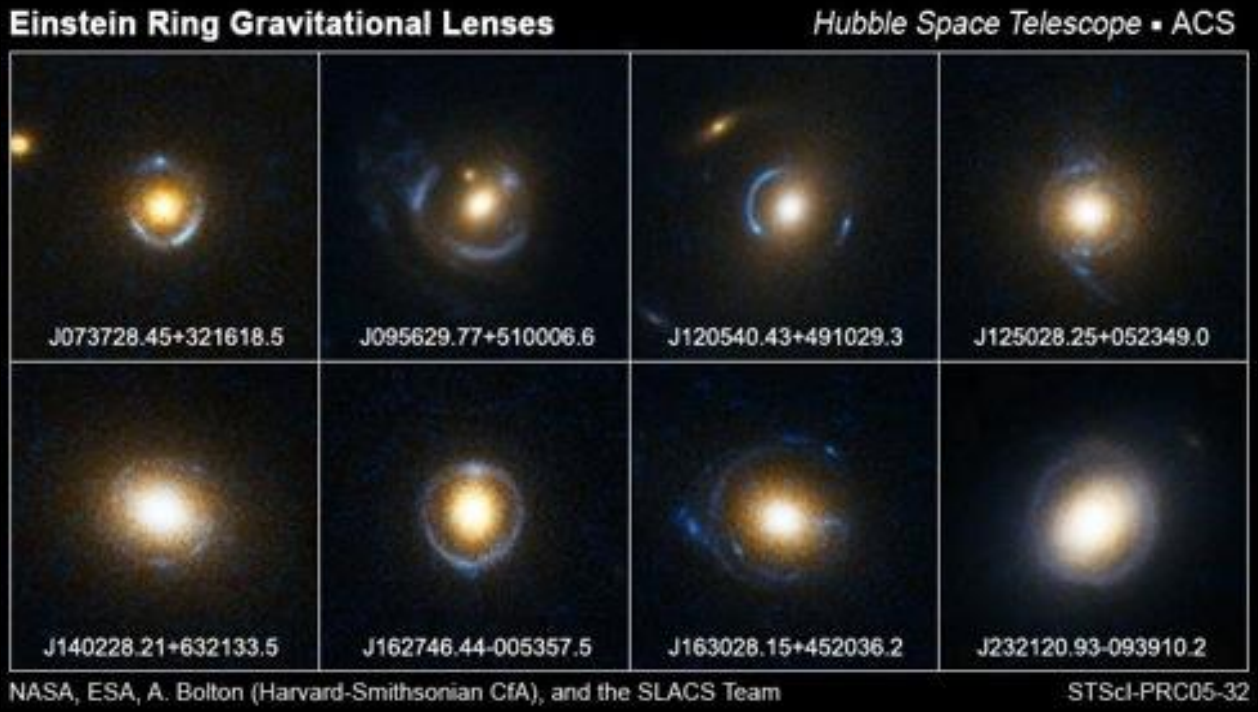
WL signal/ convergence

Tangential ellipticity

1. $$\langle \kappa(r) \rangle = \frac{-2}{\pi n_{gals}} \sum_{k=1}^{n_{gals}} \frac{\vec{e} \cdot \hat{r}}{r^2} = \frac{-2}{\pi n_{gals}} \sum_{k=1}^{n_{gals}} \frac{[e_1 \cos 2\phi + e_2 \sin 2\phi]}{r^2}$$

Other Kinds of Gravitational Lensing

- Strong lensing
- Galaxy-galaxy lensing
- CMB lensing
- Large-scale structure lensing



Other Kinds of Gravitational Lensing

- Galaxy-galaxy lensing

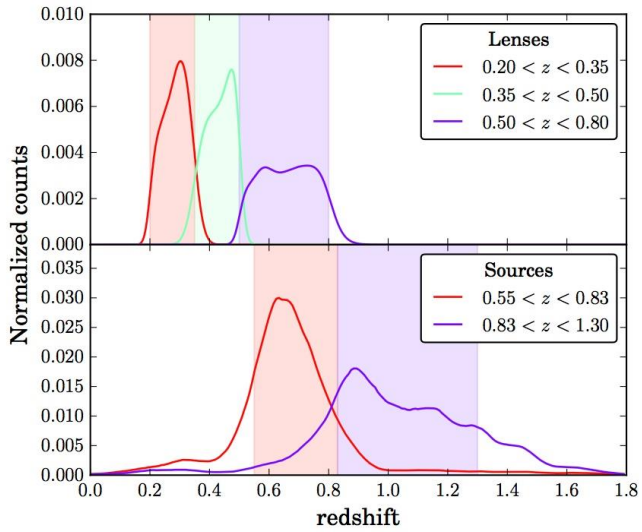


Figure 1. (*top panel*): Redshift distributions of redMaGiC lens galaxies used in this work. For lenses we show the stacked $N(z)$ from individual Gaussian distributions for each source. See text for details. (*bottom panel*): The same, but for our weak lensing source samples. For sources we show the stacked $N(z)$ from individual SkyNet $p(z)$ distributions.

Clampitt et al. (2017) arXiv:1603.05790

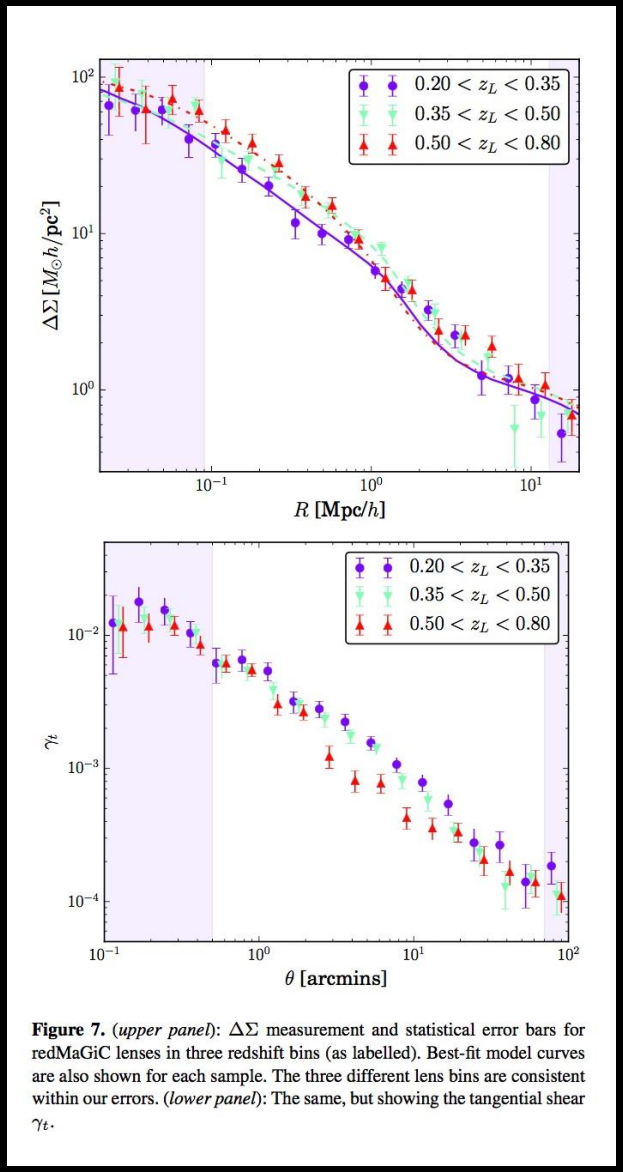
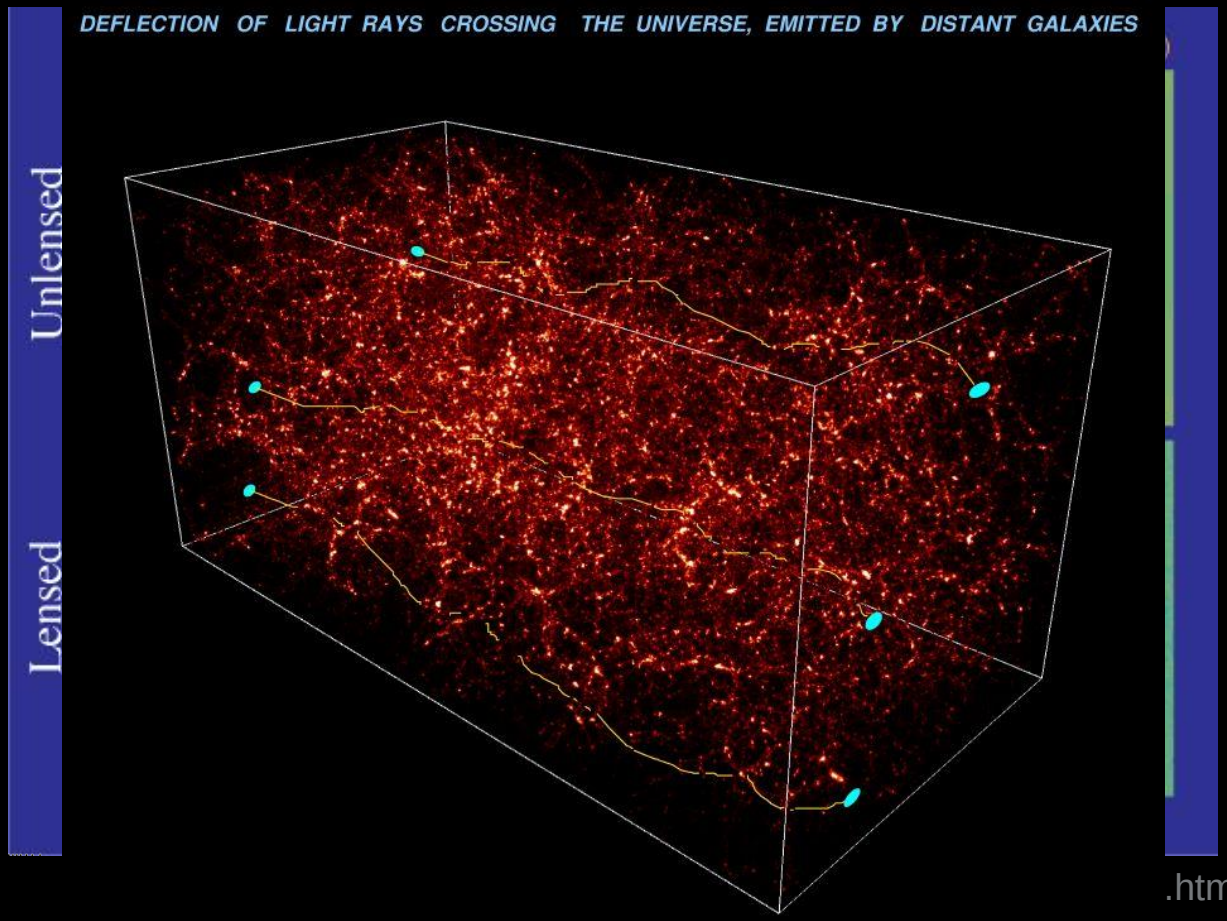


Figure 7. (*upper panel*): $\Delta\Sigma$ measurement and statistical error bars for redMaGiC lenses in three redshift bins (as labelled). Best-fit model curves are also shown for each sample. The three different lens bins are consistent within our errors. (*lower panel*): The same, but showing the tangential shear γ_t.

Other Kinds of Gravitational Lensing

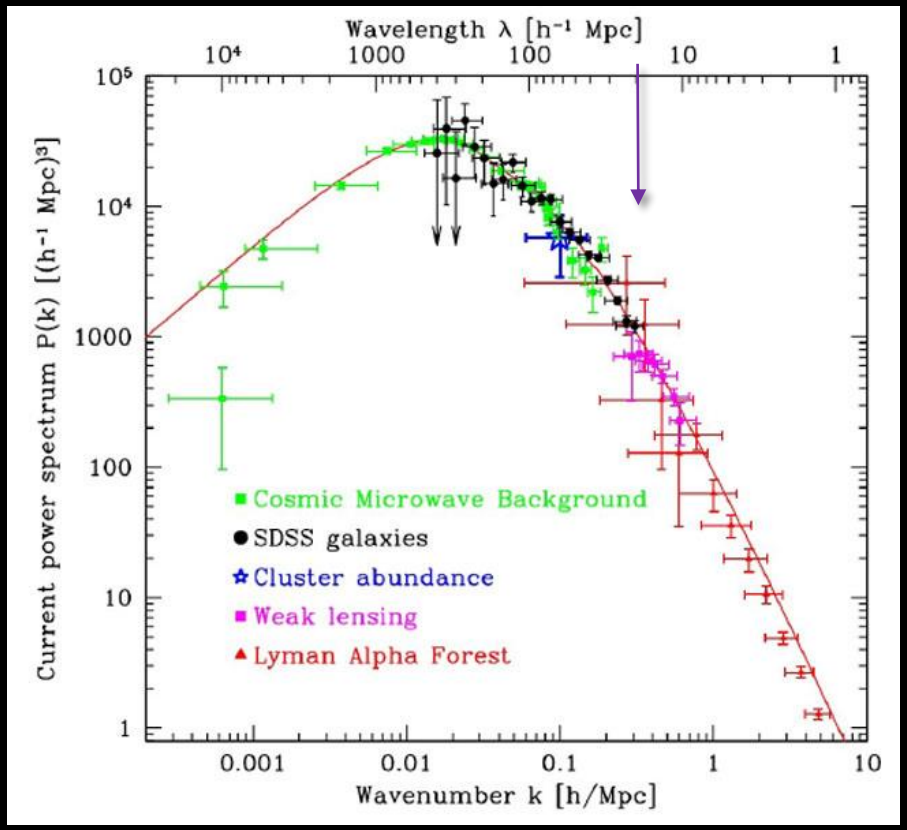
- CMB lensing
- Cosmic Shear/ Large-scale structure lensing



.html

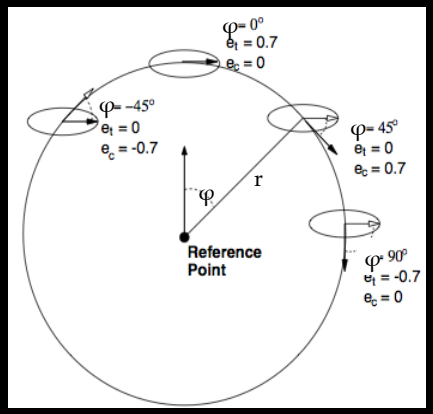
Why We Use Weak Gravitational Lensing in Clusters

- Clusters are great probes of late cosmological times, when *dark energy* becomes the dominant component of the universe
- Clusters are also a connection to gas/galactic astrophysics!
- <u>Weak</u> lensing probes clusters *all the way out to their virial regions*

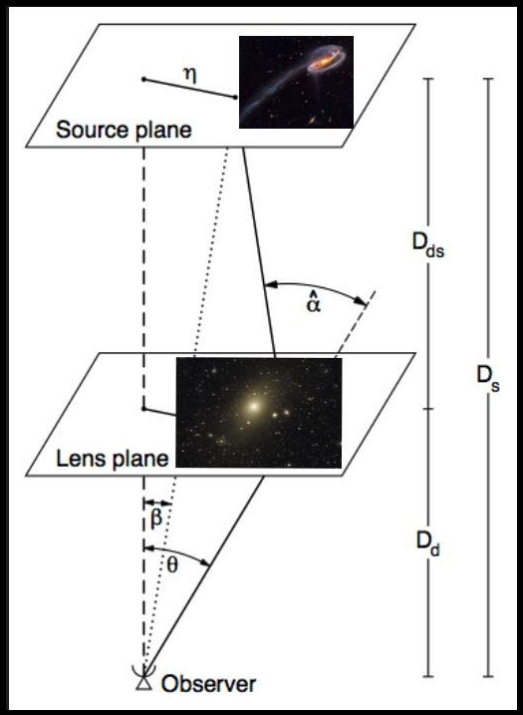


Two major pre-cursors to WL analysis:

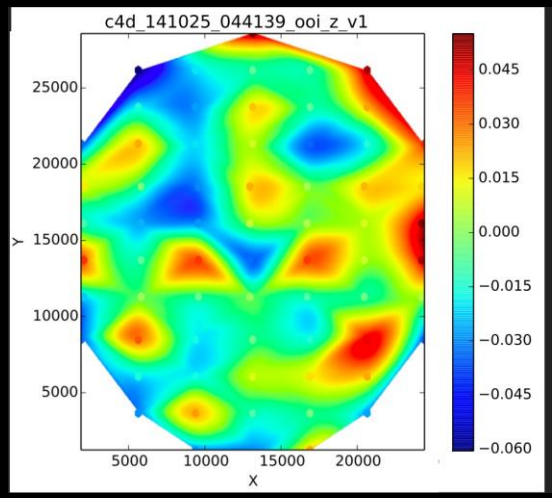
- Shapes of galaxies
  - Needed to recover ellipticity signal

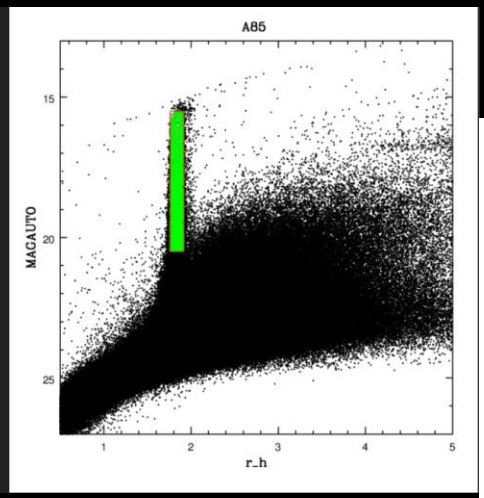


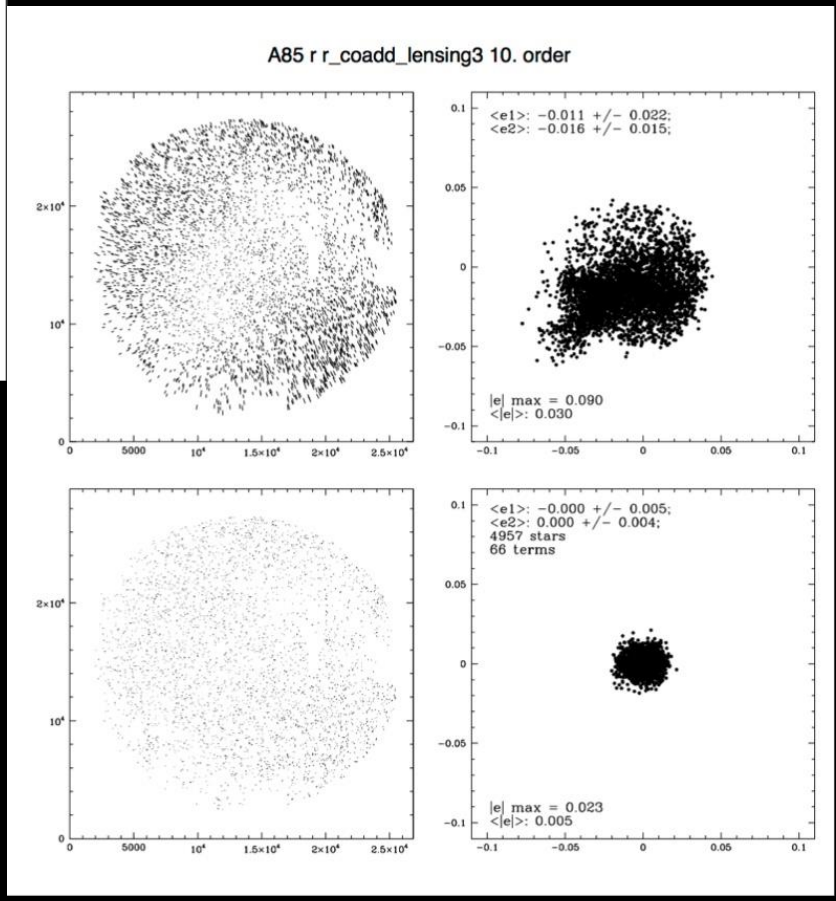
- Distance to galaxies
  - Appears in “critical surface density” needed for mass fits to ellipticity signal, $\Sigma_{crit} = \frac{c^2}{4\pi G}\frac{Ds}{D_l D_{ls}}$
  - Also needed to sort foreground and background samples!



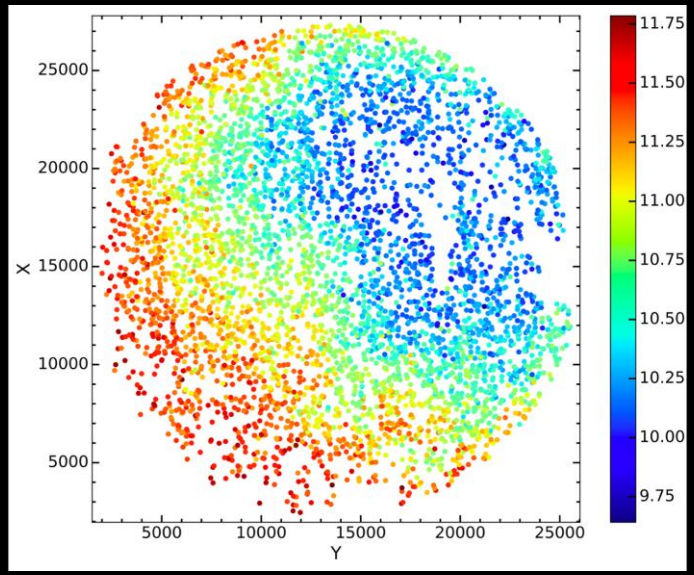
The Nuts and Bolts of WL Analysis





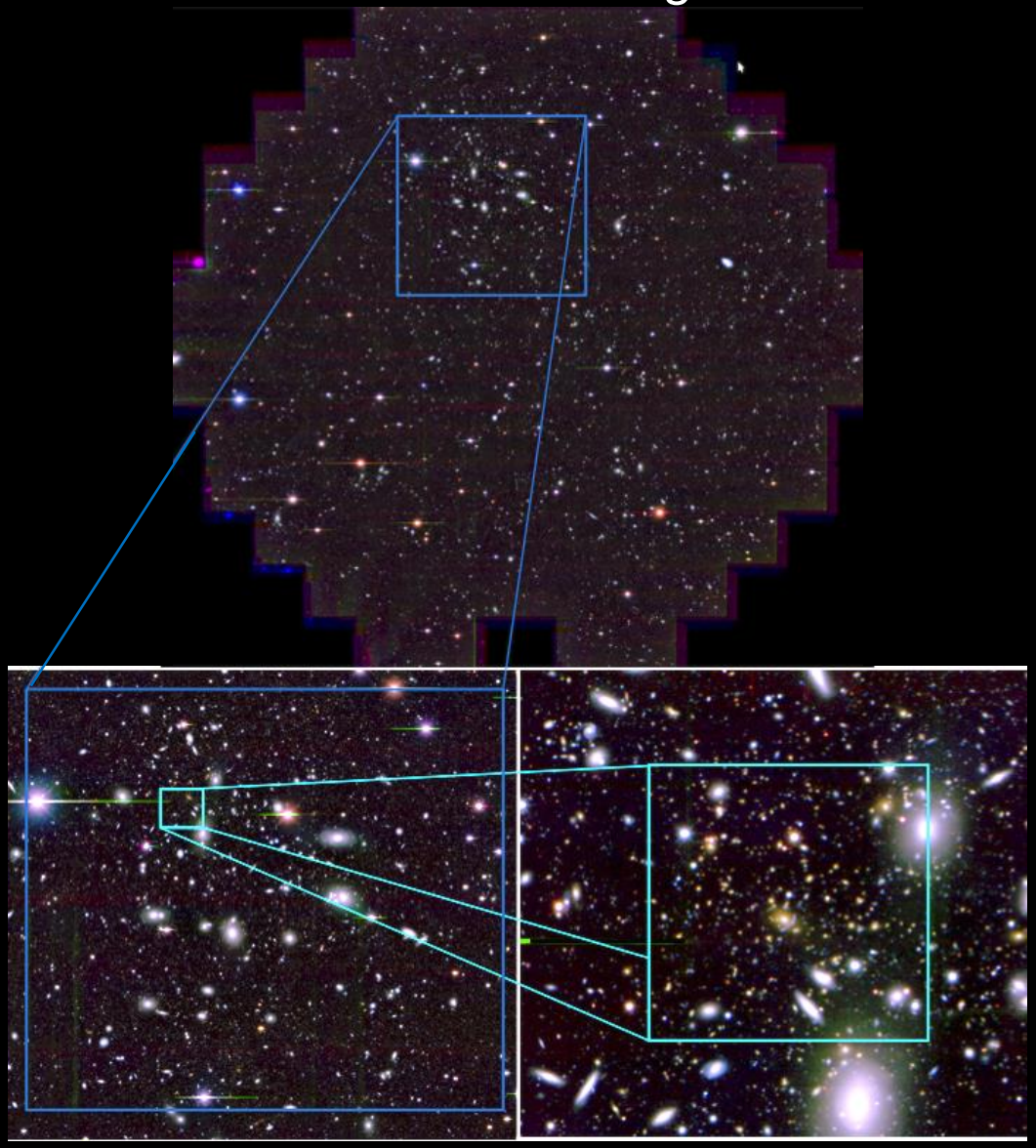


A *lot* of checking your PSF very carefully

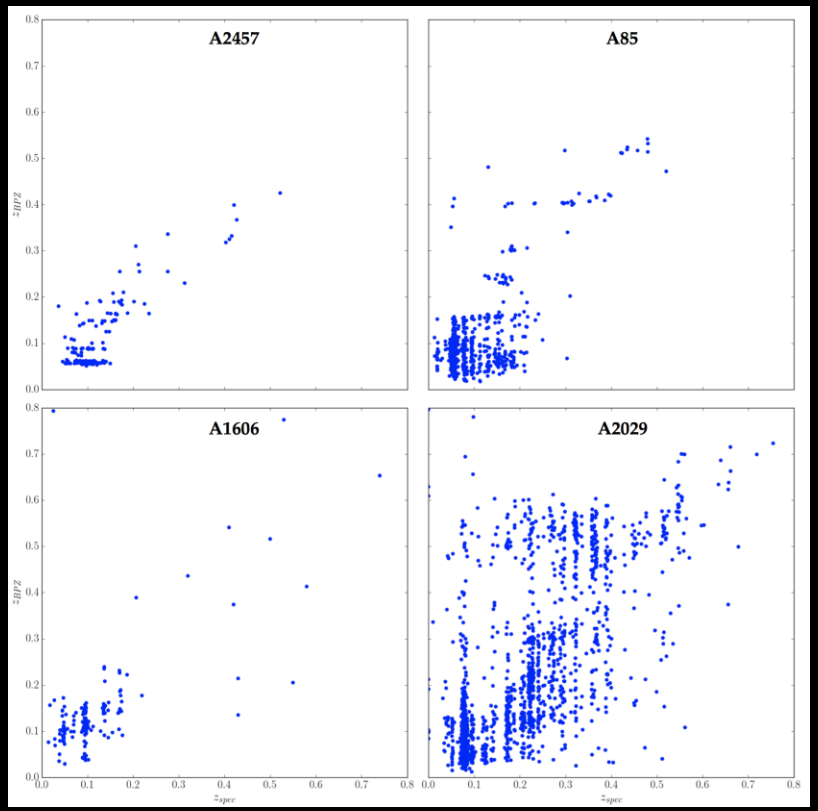


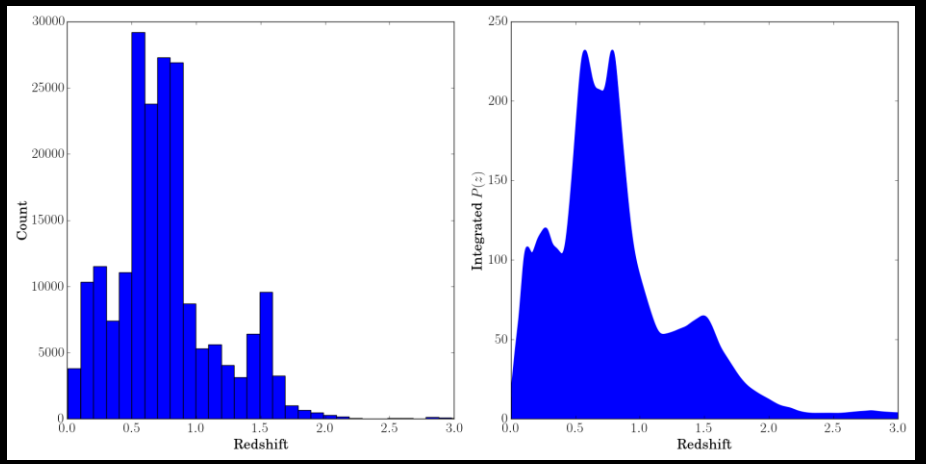
Hope you did your CCD detrending/stacking!

And that you're not some kind of idiot working on a new instrument



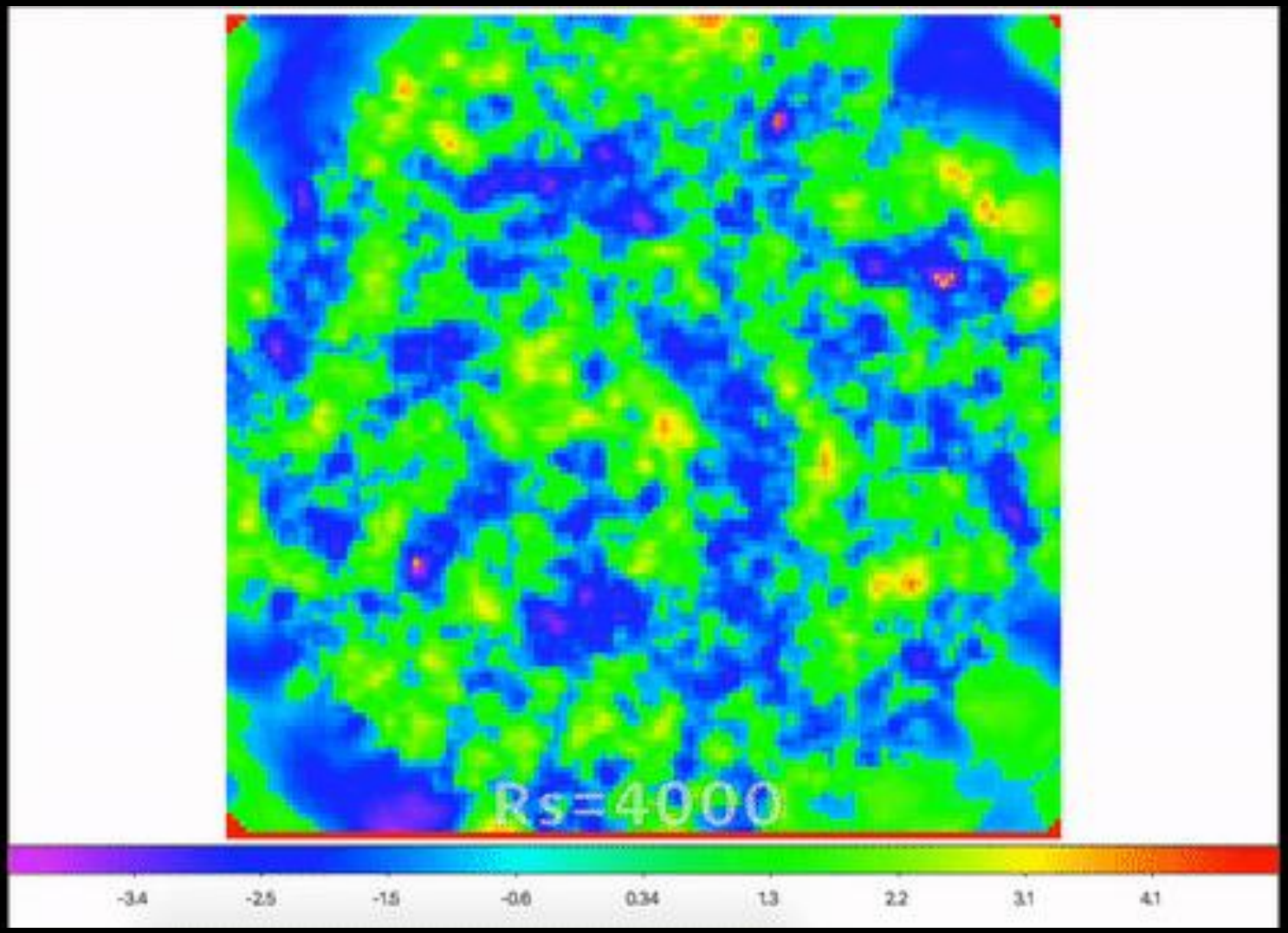
The Nuts and Bolts of WL Analysis 2: Photometric Redshift Fitting



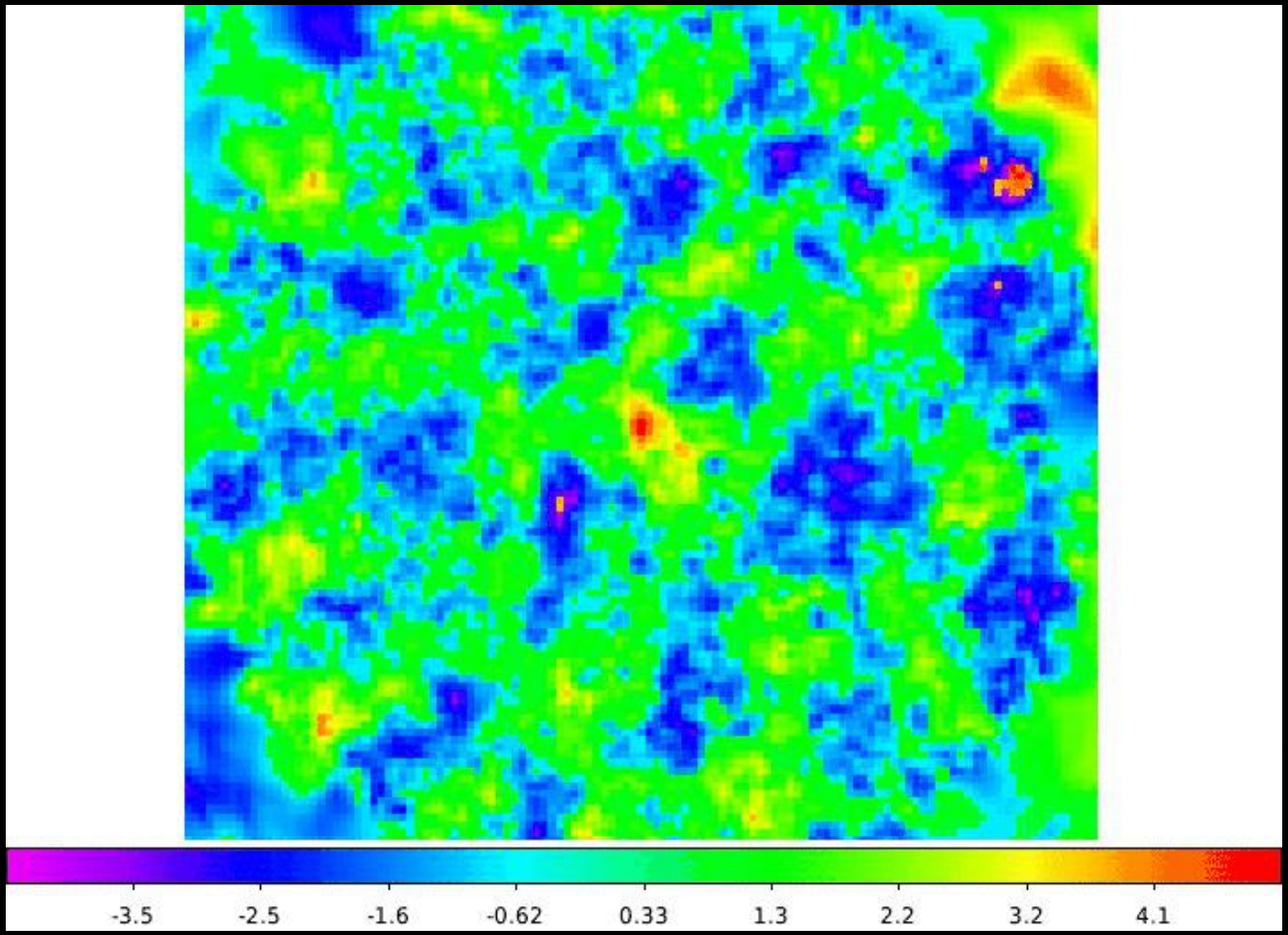


For this we (I) have used BPZ, but other options are possible…

Tuning WL Kernel to Pick out Cluster Substructure in Abell 2457

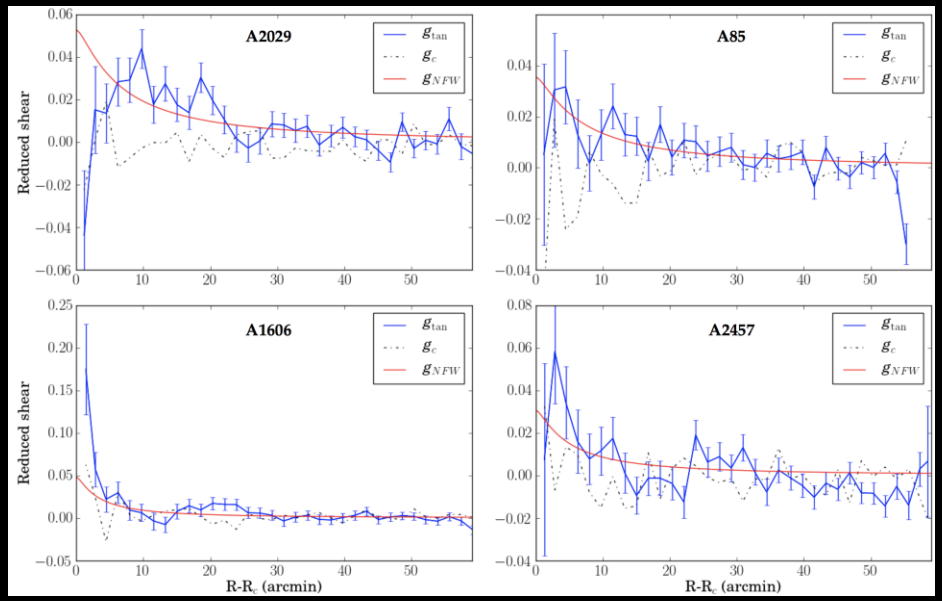


Another Example: Abell 85



Then comes fun stuff!

- Fitting Masses to clusters
- Assigning substructures to cluster (or not)
- Fitting cosmological models, if you have enough clusters
- Don’t forget null tests…



Enter SuperBIT!

- Superpressure Balloon-borne Imaging Telescope
- Examplar of NASA's new ~~ULDB~~ mid-latitude long duration balloon capability
- 0.5 m mirror, near diffraction-limited PSF, 0.11 square-degree field of view
- Wavelength coverage from 300 nm to 1100 nm

16S

15S

9S

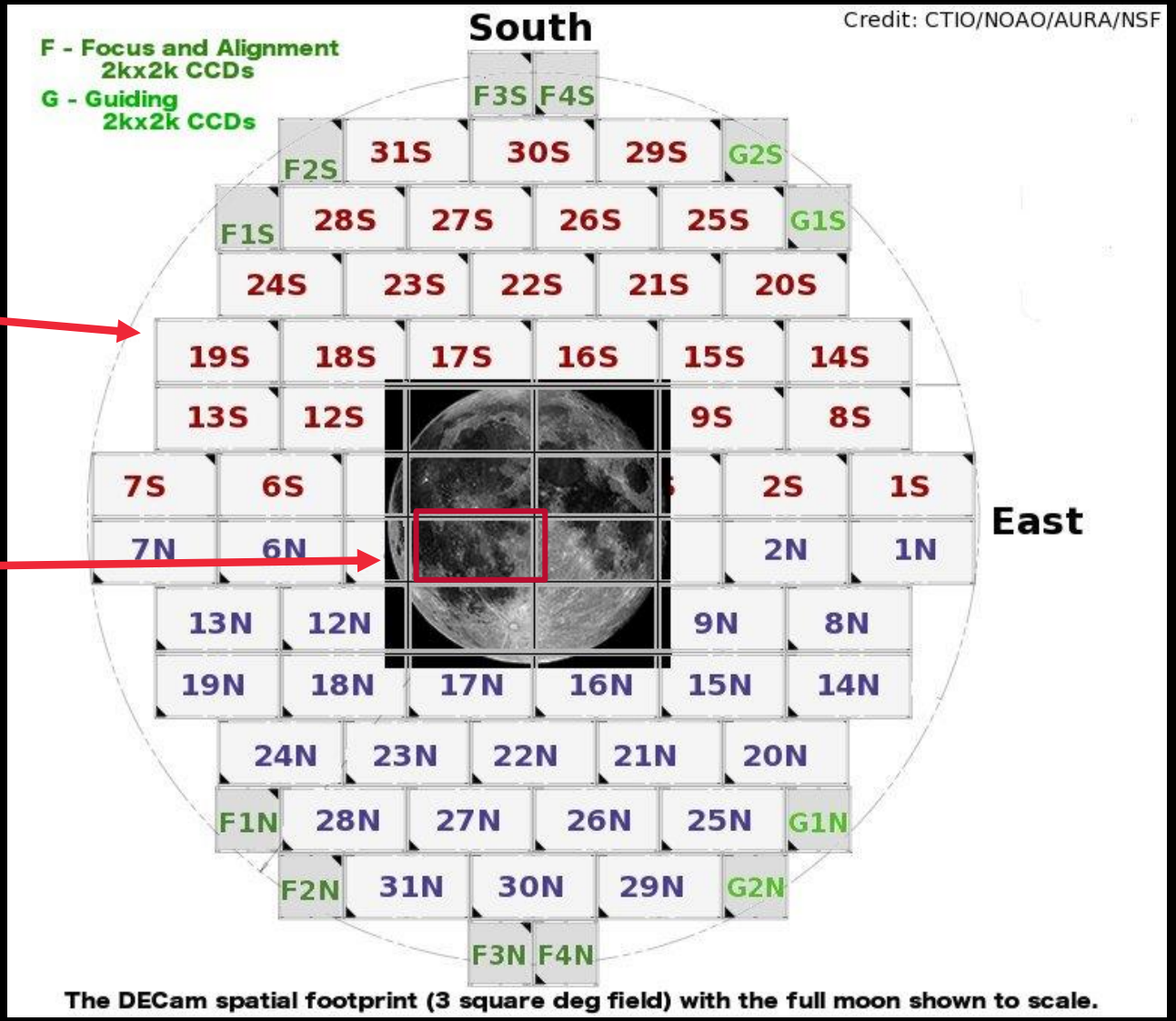
2S

2N

Field of View of SuperBIT 2

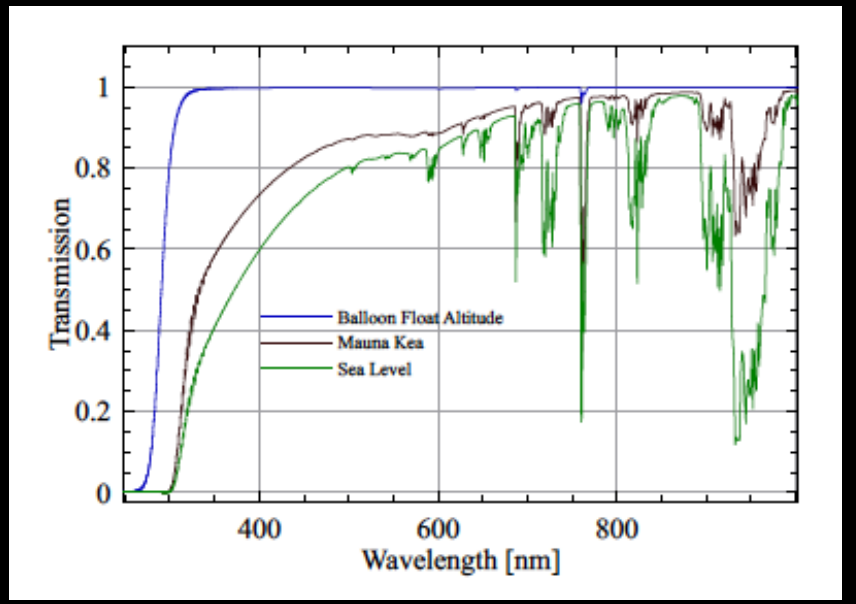
DECam field of view (camera for Dark Energy Survey)

SuperBIT FOV



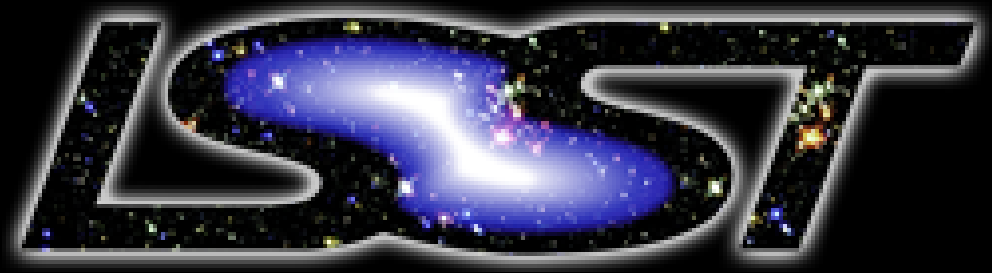
SuperBIT for Cosmology

- Core science case: ~180 clusters at 0.1 <z< 0.5
- Why do cosmologist love SuperBIT?
  - Diffraction-limited PSF for accurate shapes
  - Low backgrounds and wide wavelength coverage/speed
  - Predictable and stable observing conditions

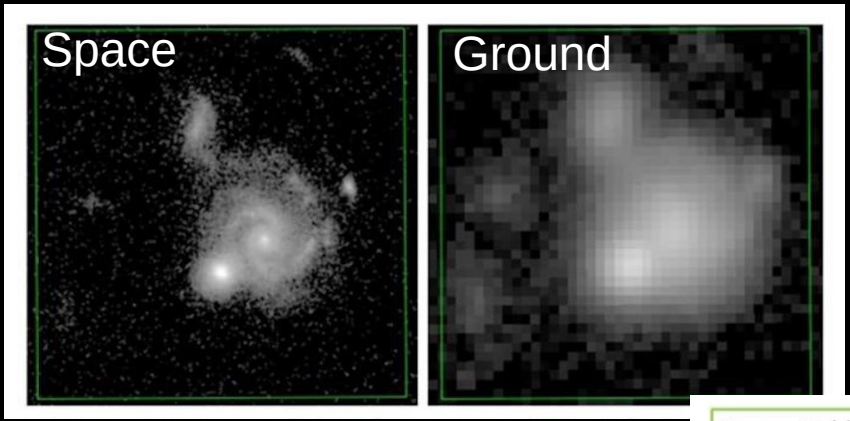


SuperBIT Cosmology: Coordinating with World-Class Surveys

- LSST, WFIRST, Euclid are going to revolutionize cosmology, but SuperBIT-like missions play a part!
- SuperBIT UV photometry would break degeneracy in low-z photometric redshifts, which are important for LSST weak lensing/dark energy studies
- SuperBIT can also help with LSST's "deblending" woes…



There Will Be Blends



- For all intents and purposes, SuperBIT is a SPACE-based mission!
- Can calibrate LSST deblending algorithms

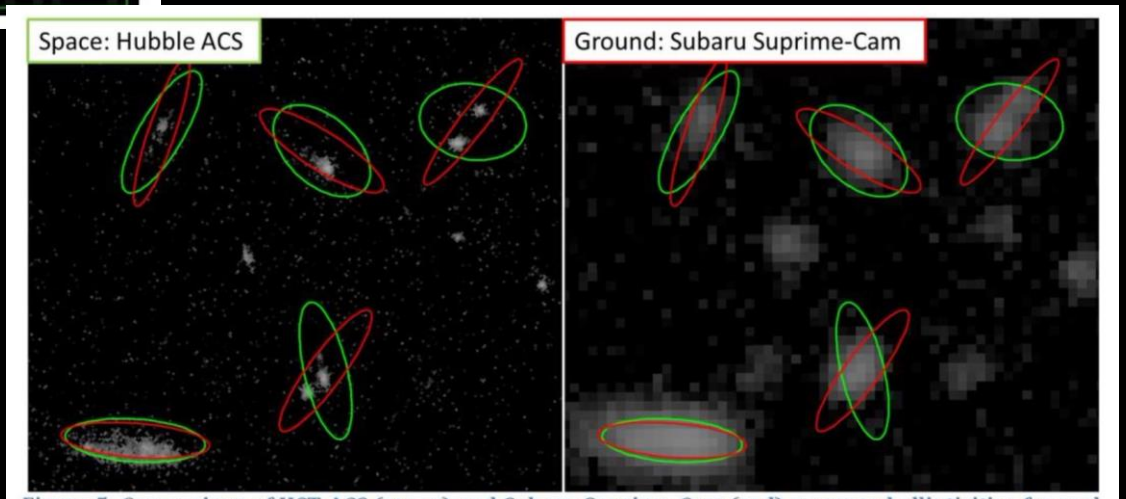
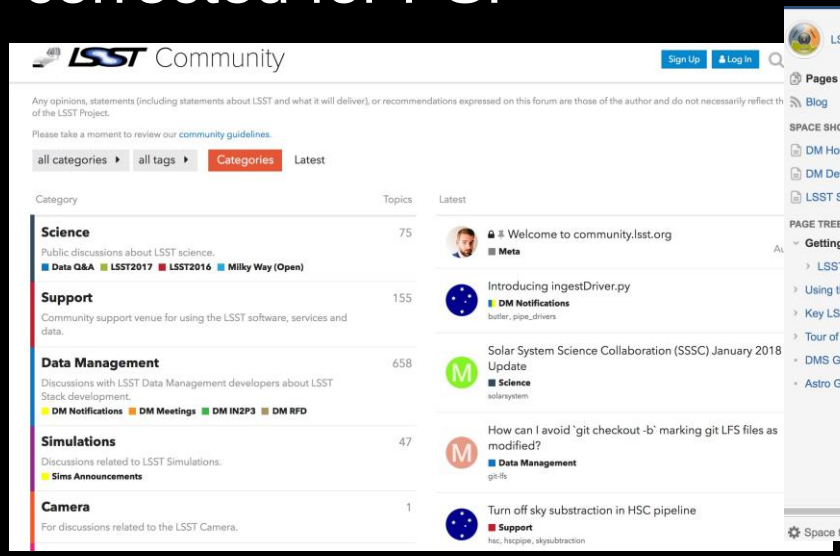
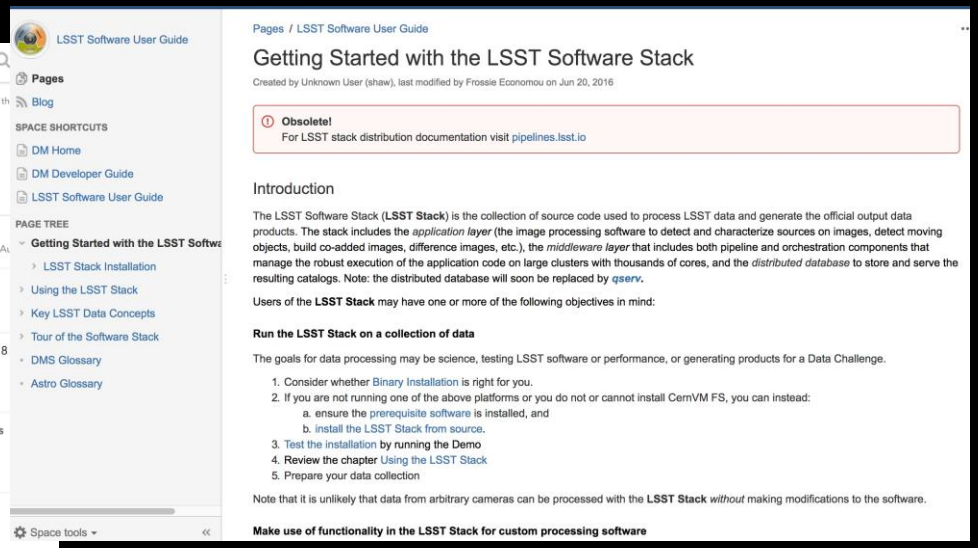


Figure 5: Comparison of HST-ACS (green) and Subaru Suprime-Cam (red) measured ellipticities for real observations of an ~10″x10″. The image on the left is from two orbits with F814W and the image on the right is the same field but observed with ~50 minutes total of Subaru *i*-band with ~0.6″ seeing, the magnitude of the galaxies are *i*~25-26. The galaxies were matched by selecting the HST galaxy closest to the Subaru galaxy center within a 1″ radius. This comparison highlights how blending in the ground-

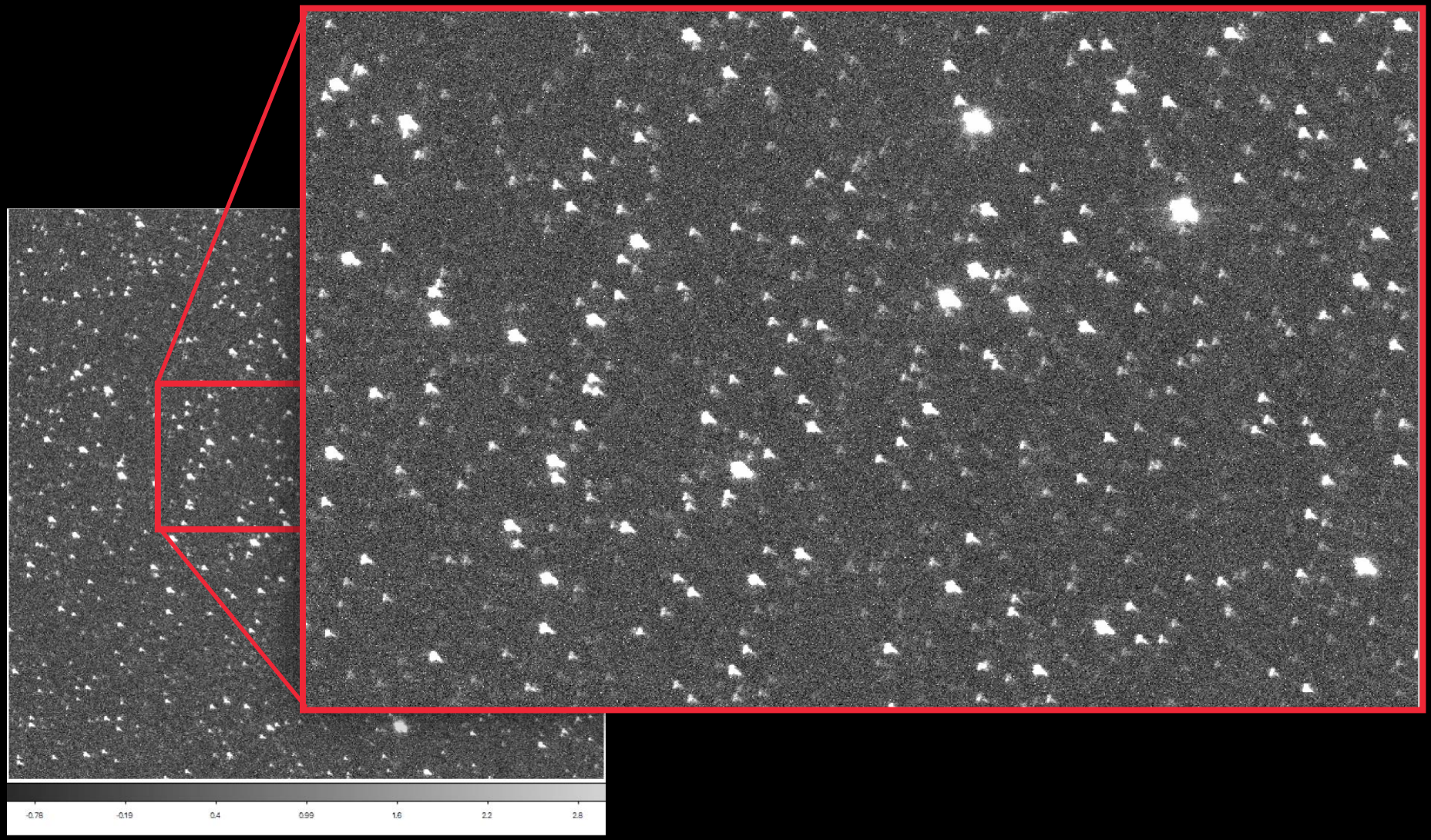
What have I been up to at JPL?

- Working on a data reduction pipeline based on the LSST science pipeline framework: **DMstack**
- Advantages: easier than rolling your own, well-vetted, readily compatible with LSST work, has community forum and documentation, a dozen GitHub projects
- Takes raw data and gives you a stack + catalog, corrected for PSF

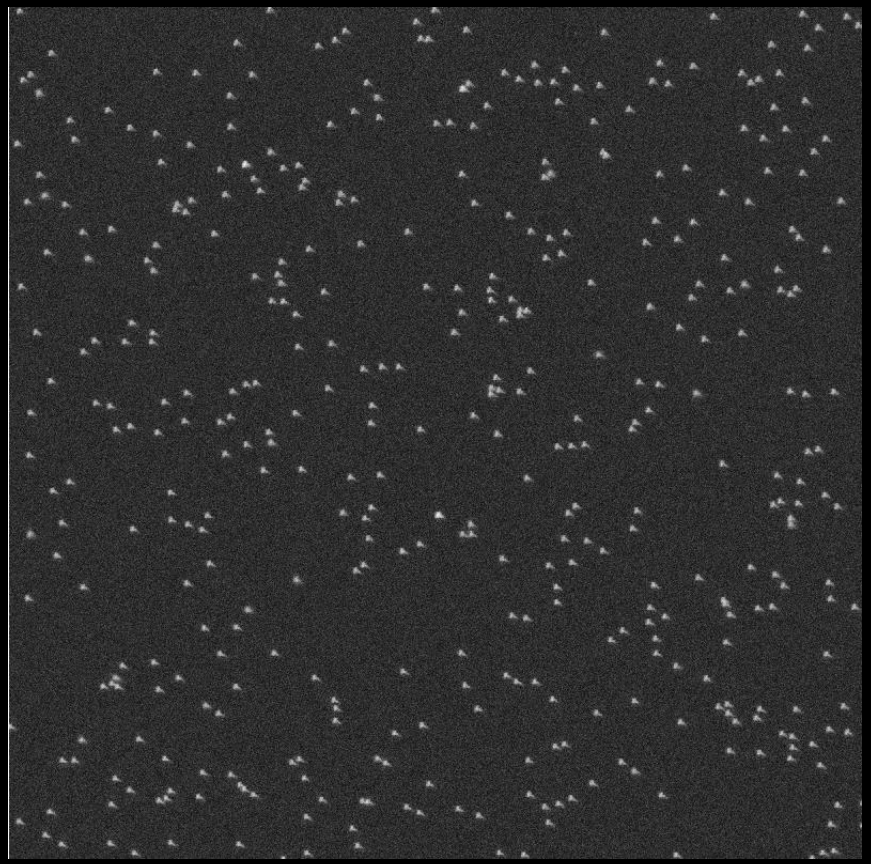




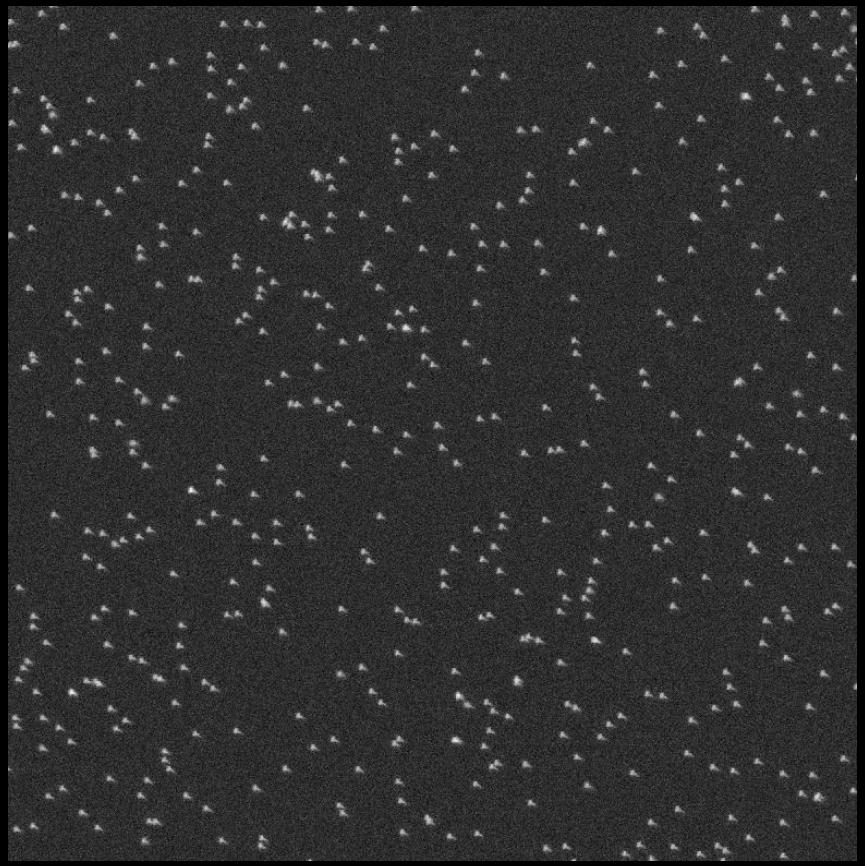
The Worst-Case Scenario



SuperBIT Simulated Observations from This PSF:



- nfw3/cluster1: S/N = 100, M_{clust} = $2.0 \times 10^{14}\, M_{\odot}$, z_{clust} = 0.05



- nfw1/cluster0: S/N = 100, M_{clust} = $7.0 \times 10^{14}\, M_{\odot}$, z_{clust} = 0.05

Simulated Observations with More Optimistic PSF

Simulations + Pipeline = Forecasting SuperBIT

- More precise simulations (Zemax?) plus a more complete data reduction pipeline will allow us to do forecasting for SuperBIT
- In turn, this allows us to decide the kind of cluster to include in the survey
  - Yes to SPT/SZ overlap…
  - Yes to LSST overlap…
  - What kind: relaxed? “Bullet” like?


JPL
Jet Propulsion Laboratory
California Institute of Technology